A Framework of e-Kanban System for Indonesia Automotive Mixed-Model Production Line

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Abstract: ***The paper describes a development framework of e-Kanban (electronic Kanban) system for Indonesia automotive mixed-model production line. It is intended to solve problems found during the implementation of traditional kanban system in the subjected company. The traditional kanban system posed inefficiencies in the production line and it has been identified in this paper. The impact is significant in causing delay information for production instruction, loss of kanban cards, inaccurate inventory, and other human-related errors. We also identified that these inefficiencies are also increasing with the increase of product variety and volume in mixed-model production line. The presented framework is the extension of the traditional kanban system that has been running for over one year in the subject company. Design framework objective is to handle all the inefficiencies problem occurred and improve the overall efficiency of material and information flow within the production line. It is a combination of paper-based kanban and software-based kanban system. Paper-based kanban handles the movement of man and material in the production line. While software-based kanban system handles kanban lot-sizing control, production instruction schedule, and integration with the subjected company ERP (Enterprise Resource Planning) system. The contribution of this work is an e-Kanban framework system for an in-house production system that employs mixed-model production line.***

Keywords: traditional kanban system, e-Kanban system, in-house production system, mixed-model production line, automotive

1. Introduction

Kanban is a Japanese word that means a signboard or card with visual information. In Toyota Production System (TPS), kanban is used to conduct the information flows in the manufacturing system to pull the material flows from upstream to downstream. The operations of various types of kanban systems were documented thoroughly by Monden, in 1993 and its implementation in the process inventory and controlling production had been proven to be effective [1]. The number of authors studied the implementation and benefit of this traditional Kanban system [2,3,4,5,6,7].

In today's competitive manufacturing automotive industry demands more accuracy, speed, and agility from the production processes [8]. Especially in recent years, product variety has been increasingly driven by rapid changes in global markets. The complexity of traditional Kanban system increases linearly with the increase of product variety [9]. The complexity is due to the limitations of traditional Kanban systems such as kanban lot sizing information control in the kanban post, handling and transferring kanban to create production line balancing, loss of kanban cards causes the production plan and forecast ability insufficient, loss control over inventory condition, and lower production efficiency. In other words, it is lack of visibility and expandability to cope with the increase of product variety.

Recently, study on an electronic Kanban (e-Kanban) system and it's advantageous over traditional Kanban system has been increasing [2,9,10,11]. The e-Kanban system of "e" stands for electronic that means the kanban system operation uses communication network and computers, in other words, the e-Kanban system runs on a network server and efficiently controlled by operators through computers. It also includes all the features of the traditional Kanban system with advantages on system traceability and scalability. With recent IT systems and other wireless technologies revolution, there has been growing interest to adopt e-Kanban to digitize the manufacturing information flow and computerize the manufacturing processes.

On the other hand, the subject company in this research is a first/ second tier of OEM (Original Equipment Manufacturer) company. It delivers components of motorcycles and cars to large Japanese automobile companies; likewise, other first/second tier OEM companies in Indonesia, the subjected company employing production facility layout based on machine functionality for mixed-model production [12], has been implemented to optimize space allocation and flexibility to do a changeover between products, because it is standard practice that first/ second tier OEM companies are producing components of more than one of the major automobile companies. This layout is different compared to the layout of major automobile companies in which employing product layout on its production line. With mixed-model production, it also presents difficulty in implementing kanban cards due to the complexity and dynamic nature in production mapping of the machines and operators.

In summary, the main purpose of this paper consists of the identification of problems on current running traditional Kanban system in the subject company, and the design of the e-Kanban framework to solve the occurred problems. It also focuses on a design the best framework to suit the company's operation management while hardware investment cost constraint and software platform constraint are taken into consideration. The contribution of this work is a framework system for an in-house production system that employs mixed-model production system while considering the optimal calculation of production schedule, dynamic mapping of machines and operators, and automatic kanban flow order and monitoring. In general, it also applicable to the other first/ second tier OEM companies in Indonesia with a similar production line.

The organization of this paper is as follows. In section 2, the preliminaries of the paper are given. In section 3, we show e-Kanban system design. While, framework development is shown in section 4; finally, concluding remarks are stated in section 5.

2. Literature Review

2.1 Mixed-Model Production

In recent times, many manufacturing companies struggle due to external and internal challenges or obstacles. External challenges arise due to product customization, high demand variability and market fluctuation, competitive cost, and quality, on-time delivery ability, shorter product life cycles, etc. [13]. This, in fact, causing some internal challenges for automotive companies to meet the requirements, and one of the countermeasures would be to employ mixed-model production line.

A manufacturing process that employs mixed-model production will have different products on the same production line or production machine. A layout of production lines is usually clustered based on its process and/ or machine similarity. The production itself manages by production schedule with a wide range of order quantity, and first in first out process is based on the kanban card [14]. It requires the production operator adaptability, and skill to produce the different specification of components, quick changeover of production tools, and accuracy in production planning; however, by employing Just In Time (JIT) technique through kanban system, the conventional kanban system suffers complexity problems due to the variety of the components.

Other authors mentioned in their researches that mixed-model production system can improve the output in machine efficiency, profitability, reduce production waste [13,15] by implementing a proper scheduling and smooth kanban circulation this mixed-model production system is manageable [16].

2.2 Traditional Kanban System

Kanban is a pulling signal for the demand of a specific product, in specific quantities of components that need to be produced in the specific process to replenish inventory after the components being taken away [2]. It manages the movements of materials and information system based on Toyota Production System (TPS) way of Just-In-Time (JIT) production process [3]. But, this kanban system is unsuitable for the manufacturing system, especially those with fluctuating demand, poor quality of production processes, or having a relatively wide variety of products [2].

The pulling signal in the tradition kanban system is a kanban card [17]. Figure 1 shows Kanban card example of the subject company. Data requirement to execute kanban process in the production line has been identified and implemented, such as part number, part name, model part, kanban number, sequence number, qty/kanban, qty/box, box type, customer, item code, current process, and next process. The information of all kanban cards displayed on a kanban board to visualize the circulation condition of the Kanban cards [2,15]. The circulation time of kanban card shows production lead-time of a specific component. Lead-time is the time needed to produce a component (cycle-time), and the time needed for material handling of a component until it stored in the inventory [3,18]. Kanban card circulation trigger manages by it lot size setting quantity. Lot size directly affects inventory and production scheduling. Lot size quantity determines the number of orders, machine efficiency for setup time or the character of the component [19].

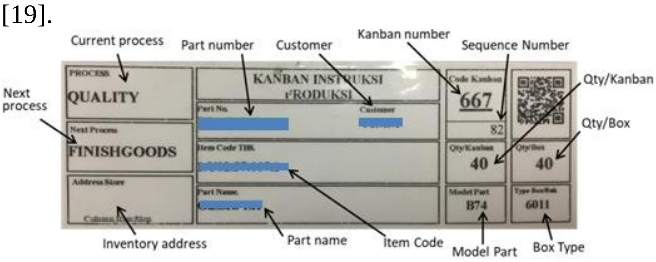

Figure 1: Kanban card example

2.3 e-Kanban System

With the advancement of IT system, the traditional Kanban system can be switched to electronic kanban (e-Kanban) system which is a computerized kanban handling system with a Graphical User Interface (GUI) deployed with desktop or web-based application technologies. Production line's kanban card data acquisition can be done effectively by employing Electronic Data Interchange (EDI), or Radio Frequency Identification Technology (RFID), or QR code/ Barcode technology. The e-Kanban system would be the best solution and an extension of the traditional Kanban system [13].

Many studies have shown that e-kanban is economical [2,9,20]. The e-Kanban system improves the plant operation by reducing the problem of lost Kanban cards, minimizing material shortage, increasing supply chain transparency, correcting the size of inventory based on demand changes [20]; nevertheless, there are some important aspects to be considered, especially constraint on the financial aspects, and the development time including integration with other system platform and training for users [9].

The kanban cards in the e-Kanban system move in one-way flow i.e., from suppliers to the company. The number of Kanban cards are controlled by using a computer. If N is the number of kanban cards for a certain part, then N is given by the following formula [21]:

$$N = [(D\ (K+L)+S)/M] \qquad (1)$$

where D is part average daily demand, K is the time interval between one order and the next order, L is lead-time, S is part safety stock, and M is the capacity of the container. The minimum and maximum of the number of kanban cards circulated in the production line determined by the customer order that has been through a heijunka process. It can be scheduled with a Backward Scheduling (BS) function. The BS function will schedule the min-max constraint changes in demand is started from its delivery date.

Major automobile manufacturers has been employing an e-Kanban system in their production line. The ordering system is dedicated to each of the suppliers according to its address mentioned in the e-Kanban database, and the suppliers just need to download the e-Kanban information from the system; therefore, it makes less error in the production and delivery system of the suppliers [22,18,23].

3. e-Kanban System Design

3.1 Brief of the Subject Company

PT. Trimitra Chitrahasta is a local company established in August 1994 and specialized in Metal Stamping, Dies, Jig, and Fixtures for automotive in Indonesia. The company plays an important role as a first/ second tier of Original Equipment Manufacturing (OEM) company. Currently, the company business is progressing, and it produces more variety of automotive components which include 2-wheel and 4-wheel components. Main products of 2-wheel components such as handlebar comp, stay headlight, bar comp footrest, etc. Main products of 4-wheel components such as pedal assy brake, crossmember comp, base comp battery set, etc. Due to the variety of the components, it employs a mixed-model production line to produce a variety of components.

The production line layout employs mixed-model production process as it is shown in Figure 2. It consists of the stamping process, welding process, and assembling process. Each of the processes consists of several types of machine that setup according to the product requirements. There is no dedicated machine or line process for one component, each of the machines serves multiple productions of components and different setup. In general, based on the interview result with the user, most of the first/ second tier OEM companies in Indonesia employs the same production layout.

From the ever-increasing competition in the business, the company develops reliable and good quality products to the customers and strive to continuously improve manufacturing productivity and quality by employing TPS to obtain thorough lean production in all the production lines. The management considers TPS kanban method system as one of the important tools to maintain the stability of production line in fulfilling customers demand. The traditional Kanban system has been employed and studied for these past three years. In general, the major Japanese manufacturer always deterrent to employ TPS system, including kanban system, to its first/ second tier OEM companies.

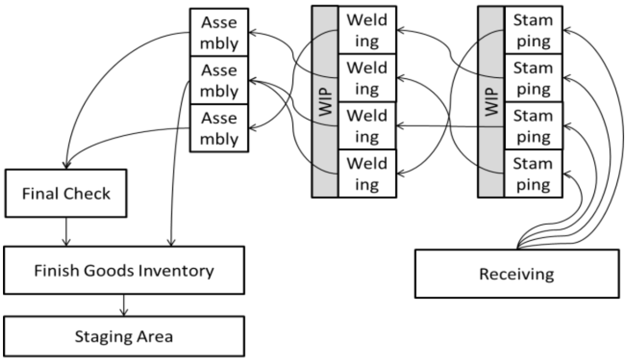

Figure 2: Mixed-model Production Layout of the Subject Company

3.2 Current Situation of the Established Traditional Kanban System

Figure 3 shows the Material and Information Flow (MIFC) chart of the production line. Its in-house production line includes Stamping Line, Welding Line, Quality Control (QC) Check Line, and Assembly Line. Work-In-Process (WIP) inventory area established in between each process, and finish goods (FG) storage area put in place for final storage before the components delivered to the customers.

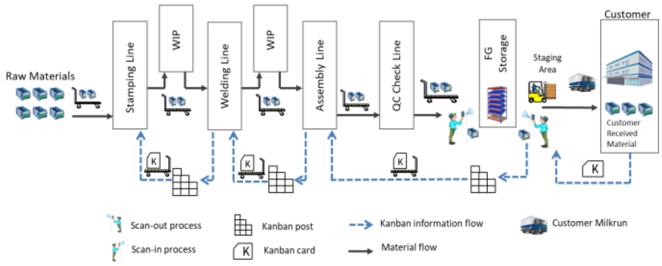

Figure 3: Material and Information Flow Chart of the Subject Company

When the customer sends pulling kanban card, delivery Person In Charge (PIC) prints it. Based on it, delivery PIC goes to FG inventory area and unload the required components from the storage area. The components and it's boxes then delivers to the staging area, before that, delivery PIC does kanban scan-out at the FG inventory area exit gate and detach the kanban from the box and then put it in the kanban post. The "Milkrun" (customer appointed third-party delivery service) then comes according to the pick-up schedule and loading the prepared components to the truck and deliver it to the customer [24,25,23].

In the kanban post, all the kanban cards are waiting to be delivered to the previous process by the "Kanban Boy". The kanban card will through lot making process in the allocated space inside the kanban post. Lot making process is the kanban card waiting for the process until the total number of kanban card match with lot making quantity requirement. The quantity of kanban in one lot differs according to the production cycle time of each component in the previous process. Figure 4 shows the kanban post used in the subject company.

Figure 4: Kanban Post Example

Once the quantity number of kanban match with the lot size requirement, then the "Kanban Boy" delivers it to the previous process which is Assembly Line. To do the production, supply material transfers from the Assembly Line WIP to the designated work table. The supply material kanban detaches from the box then put it in the allocated kanban post near the gate out of Assembly WIP. After that, the production process takes place, and when it finished then the components deliver to the FG inventory area with Kanban card attach to the side of the box. At the entry gate of FG inventory area, this Kanban card is scanned-in then the components deliver to the designated storing area. Hence, the 1st-cycle of the kanban card in the in-house production line finished.

After that, the 2nd-cycle of the kanban card comes from the supply material that delivers to the assembly line is starting its lot making in the WIP Assembly kanban post. Once the number of kanbans matches with the lot size requirement, then another "Kanban Boy" delivers it to the previous process which is Welding Line. The process keeps on going until the supply of raw material into the stamping process.

Currently, there are two types of Kanban cards utilized in the production line. The kanban cards attach with QR code, and the kanban cards attach without QR code. The QR code attached kanban cards only works for the final process of the component production. The system is employed to improve the accuracy of the FG inventory area material control, and faster data transfer into the ERP system [25, 23].

The information flow of the QR code attached kanban cards as shown in Figure 5. The scanned kanban data once manage in the local database server, after that, the data is transferred to the ERP database by automatic data export application. It framework only allows for one direction flow of data transfer which is to feed ERP database. The function of this is to get better insight and monitoring of FG inventory since it is critical function as buffer of the delivery system. It also to create faster data acquisition to the ERP system due to the high quantity of components variety because the manual data entry always fell behind several days from the actual transaction day.

The traditional kanban system works as described and after three years in operation, management team identified that several problems have occurred and need to be improved.

a. As the variety of the components increased, the number of kanban cards in the production line also increases. It needs bigger kanban post to handle the lot to size control of each kanban cards. Hence, it takes a longer time to manage the handling of kanban cards from finding the correct allocated space, counting the number of kanban cards in the kanban post, sorting the kanban cards that fulfills one lot size requirement, and the delivery of all the kanban cards to the designated production process.

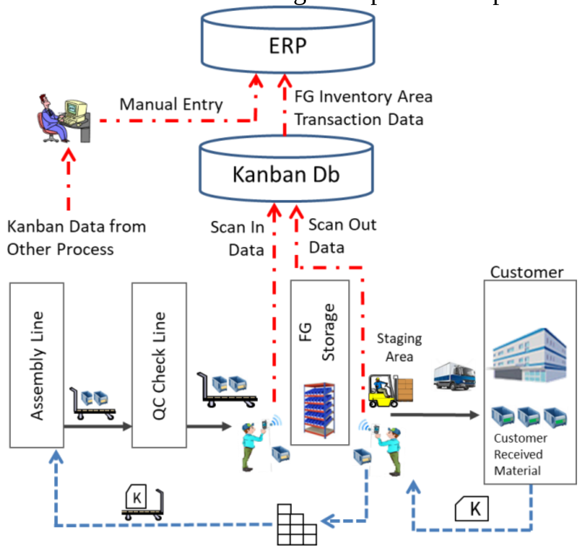

Figure 5: Data Information Flow Layer

b. From the above problem also indicated that it was very difficult to maintain the correct number of kanban cards circulated in the production line in response to the changing of order from the customer. This caused either of these two problems, inventory will be overflow if the order quantity decreased, or shortage in the inventory if the order quantity increased.

c. It is difficult to do monitoring of the time that needed for the kanban cards to finish one-cycle or known to be kanban lead-time. Lead-time needs to be monitored to check production efficiency and alertness, this is important data for the management team to do production analysis for improvement. Only kanban cards in the final process currently employed QR code system for faster data transfer and monitoring.

d. The kanban cards are often lost within the production area due to the negligence of the operator and the "Kanban Boy" in the production line, and this difficult to be monitored on a real-time basis. This will impact the number of the components that need to be produced. Hence, the daily demand cannot be achieved and disturbed the delivery.

e. The "Kanban Boy" job function is important to circulate Kanban cards in the traditional Kanban system. Hence, it always considers as an additional cost of manpower to maintain the kanban cards circulation smoothly and looking at the local manpower lack of skill and attitude the problem in kanban cards circulation often occurred.

f. Current data transfer structure between ERP database and FG inventory Kanban cards database only allows one-direction of data to ERP database. While FG inventory Kanban cards database needs information such as components detail data, components Bill of Material (BoM) to be managed before the kanban cards printed out, circulate and scanned that available in the ERP database. Hence, FG inventory Kanban cards database still manually controls which lead to human error due to the high variety of the production components.

g. Production planning also still be done in an old-fashioned manner utilizing general spreadsheet software in the monthly and calculation of production schedule. The production schedule is distributed manually to the production line by paper. While the level of stock in each WIP area still monitored manually, then it is very difficult to get accurate data to do production scheduling and machine loading or manpower working hour calculations.

3.3 Concept and Design of e-Kanban System

The system is an extension of the traditional Kanban system that has been established in the subject company. Totally it has more than nine hundred of final assembly components that need to be delivered to the customers, while the production line itself must handle more than three thousands small parts to produce these final components, while in the other hand, it also must quickly respond to the rapid changing of customers demand. Hence, it is clear that the established kanban system need to be digitized into an e-Kanban system [2], [26].

According to the identified problems in section 3.2 and to help the subject company improving their lean production system. We designed an e-Kanban system for the in-house production system. The ordering system itself is taken from the idea mentioned in the last paragraph of subsection 2.3. Instead of ordering the e-Kanban to suppliers, we designed so that it will put an order of e-Kanban to the in-house production system, specifically to the dedicated line/ machine or inventory of the component.

Figure 6 shows a general operational and hardware design of the e-kanban system. It is designed to solve all the traditional Kanban system problems that have been identified in Section 3.2 above. In this e-Kanban system, we utilize two functions of kanban card: software-based kanban card, paper-based kanban card. Software-based kanban card is a kanban data information manages in the network server. Paper-based kanban card is a printed kanban paper use for production instruction, WIP or FG inventory areas scan in and scan out. It also has two types of kanban card: Production Instruction (PI) Kanban, and Parts Withdrawal (PW) Kanban [Naufal *et al.*, 2012]. The PI Kanban is used to place an order in the production line according to the data contains in it. The PW Kanban is used to supply a material to the production line from WIP inventory area.

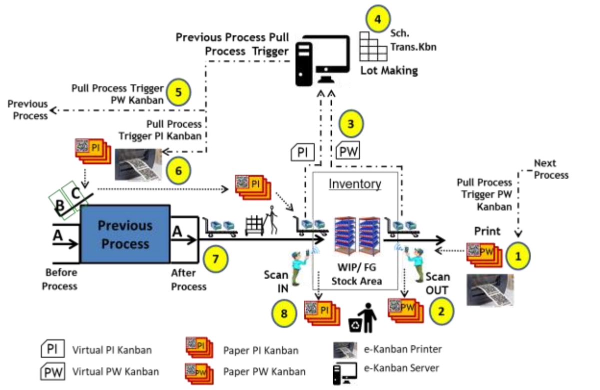

Figure 6: A General Operational and Hardware Design of the e-Kanban System

Paper-based PI Kanban and PW Kanban serve its function in "one-time flow" manners. It means that for PI Kanban, it lifetime is from it is printed, put in place for a production, attach to the box of the finished components, and scanned-in at the designated entry gate of WIP or FG inventory area. While for PW Kanban, it lifetime is from it is printed, take into the WIP or FG inventory area, attach to the box of the unloaded components, and scanned-out at the designated exit gate of WIP or FG inventory area before it delivered to the production area. The PI Kanban printer will be placed on the designated production leader table, the PW Kanban printer will be placed on the designated WIP/ FG inventory leader table. Printing order of each kanban in each of the designated WIP/ FG inventory or production process will be redirected through IPv4/ IPv6 intranet scheme [26,27].

The e-Kanban system tool has been developed mainly for the subject company production system, but, it can be also extended into other mixed production line manufacturing environments. Figure 7 shows a general software design of the e-Kanban system looking from the system main inputs and outputs.

The e-Kanban system needs an up-to-date inventory data of every component it controls before it releases order for each one of it. Information about real-time on-hand quantities in each WIP/ FG inventory, changes in components quantities due to material receipts, stock withdrawal, stock tacking update on each of the WIP/ FG inventory is stored in a database named Inventory Record (IR). Data stored in IR contains important information to be used by other departments such as purchasing, cost control accounting outside PPIC and production, in which include: part number, part name, part type, customer id, item code, lead-time, lot-sizing quantity, safety stock, safety lead-time and linkage to the BoM database.

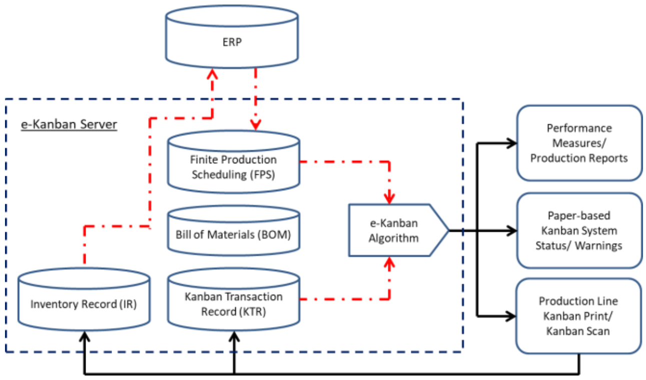

Figure 7: e-Kanban System Main Inputs and Outputs

The Bill of Materials (BoM) database consists of an association of components and its raw materials with the operation that requires them in the routing sequence. Thus, this database links all parents of a material to its child material and vice versa. The function of BoM is critical for the integration of material planning and linkage between PI kanban and PW kanban. PI kanban considers as a parent component to be produced in the production line. PW kanban considers as a child component to be supplied to the production line. Child components supply to the line from WIP inventory by using PW kanban to produce a component of PI kanban. The paper-based of PI kanban and PW kanban condition in the production line links to the KTR database.

The Kanban Transaction Record (KTR) database consists of information about real-time paper-based PI Kanban and PW Kanban conditions including changes in Kanban status due to material receipts (kanban scanned in/ out FG or WIP inventory), part withdrawal (kanban printed), waiting for lot size quantity (kanban waiting for lot size), or even kanban unmoved/ lost. Data stored in KTR contains important information such as part number, part name, part type, customer id, item code, lead-time, lot-sizing quantity, safety stock, safety lead-time, printed date/ time, scan date/ time, and linkage to the Finite Production Scheduling (FPS).

Orders released to the production line from the ERP database are directed to a dynamic Finite Production Scheduling (FPS) database to calculate and allocate them to specific resources based on the lot-sizing technique, and the production load balancing technique. Orders are broken down into its child parts component production jobs, which in turns consists of a number of tasks that need to be done in a specified production process. Schedule of tasks are constructed on the basis of events occurring sequentially through work time schedule. All operations eligible for production at the time a resource available is also considered, in which the linkage between IR, KTR, BoM with FPS is important. Other operations such as urgent orders, changing orders, and other dynamic condition that needs manual adjustment by PPIC operator is also considered, in which priority based production schedule is also important.

The e-Kanban algorithm as shown in Figure 7 is the engine of the system. It coordinates the operation of the system's input and output databases/modules. Top priority of e-Kanban algorithm, the FPS schedules orders on daily basis operations starting at the bottom level to the top level of the components respected BoM as a Backward Scheduling (BS) function [26,28]. This calculation serves as a minimum component quantity that needs to be produced on the respected working day. Hence, whether the customer sends the pulling kanban for delivery or not, if the stock quantity on WIP/ FG area less than the BS function result, then PI kanban and PW kanban will be ordered to start the production process for safety stock level adjustment. Next priority, the lot-sizing technique determines cumulative order's lot size. It is based on the premise that the sum of components or ordering cost and inventory carrying cost will be minimized. If the customer sends the pulling kanban, and it's sum matching with the specified lot size of the components, then PI kanban and PW kanban will be ordered to start the production process to replenish stock level. The order of PI kanban and PW kanban comes with auto-print kanban paper in a designated production process to minimize human error.

3.4 e-Kanban Application Architecture and Feature Menu

An open-source platform infrastructure has been designed for hosting e-Kanban system due to budget constraints of the subjected company. A combination between a web-based application and a desktop-based application will synchronize the function of providing dynamic Graphical User Interfaces (GUI) to the users including management, and the function of real-time task scheduler to maintain smooth operation of the e-Kanban system in the production line. The security concept will include the availability of Information Technology (IT), network security, software application security, and data security [27].

On the web-based application, the Apache HTTP server handles the HTTP requests and operates as a connector between e-Kanban application, and the subjected company Intranet Network. We employ the Model-View-Controller (MVC) architectural pattern using the PHP Laravel platform. This is a robust architecture that allows systematic database management, and also allows rapid custom made of GUIs through the combination of HTML, CSS, JavaScript, and Java programming languages.

On the desktop-based application, the .NET platform handles a lower level of a user interface in the production line. We employ it for a kanban print application and kanban scan application due to its efficiency and faster development time.

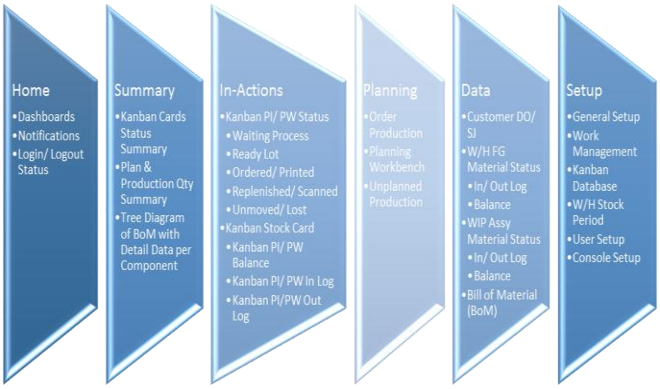

Figure 8: e-Kanban system feature menu of the web-based application

Figure 8 shows e-Kanban system feature menu of the web-based application. It is designed to meet user demands and requirement to provide insight of the overall and detail of the e-Kanban system that circulating in real-time in the production lines. It is also designed to make the user easily operate the system by automatically or by manually. IT staff for development system provides maintenance, software improvement. Software improvement will be easily done since it is using the open-source platform.

4. Results and Discussion

The designed framework is based on the traditional Kanban system problems on current reviews of the subjected company. Several authors has been shown the benefit of e-Kanban system to improve efficiency in production process flow [2, 26, 29, 27], but most of the cases shown that the system is implemented to handle production process between in-house factory and supplier. We propose that the system also can be employed in the in-house production line with large production floor while solving the inefficiencies problem occurred.

The benefit of this framework is analyzed to show that it is expected to solve the problems and help to improve operational management once it is implemented. We have been identified seven crucial problems and in high priorities to be solved. The first identified problem is bigger space allocation for kanban post to handle the lot-sizing control of each kanban cards. Bigger kanban post also made longer handling time to put-in kanban card in the designated place or take-out the correct kanban card from the post. This has been causing inefficiency in space allocation and handling time. With the proposed framework, kanban post is not needed. This is due to lot-sizing control of each kanban cards will be processed in the e-Kanban server; therefore, it also reduces handling time kanban cards.

The second identified problem is that it was difficult to maintain the correct number of circulated kanban cards in the production in response to changes in order demand. Maintaining the correct number of circulated kanban cards will be easier, since the application employs FPS for the daily basis minimum production process, and kanban pulling system automatically triggered with lot-sizing technique to print kanban.

The third identified problem is that kanban cards one-cycle lead time cannot be monitored on the real-time basis. The e-Kanban card employs "one-time flow" rule with the printed kanban card at the beginning of the cycle and the scanned kanban card at the end of the cycle. The event changes to date and time are all recorded in the application. Hence, lead-time monitoring will be feasible.

The fourth identified problem is lost of kanban cards, monitoring limitation in the production line. This problem can be solved due to the application records all the event changes occurred for each kanban. Hence, lost of kanban cards can be monitored directly.

The fifth identified problem is the requirement of additional manpower that works as "Kanban Boy" to circulate kanban cards between processes. This problem also can be solved due to e-Kanban card employs "one-time flow" rule. Therefore, kanban circulation to the previous process is not needed. The application handles kanban lot-sizing calculation, and once the requirement fulfilled then it will do auto-print of kanban in the designated production process. Hence, "Kanban Boy" manpower can be reduced.

The sixth identified problem is the traditional Kanban system that implemented in the subjected company only has limited capability. The scan-in and scan-out database only to store FG inventory area of kanban transaction, and the second feature is automatic data transfer to ERP database. By employing FPS, BoM, IR, KTR databases/ modules, we have more detail data to be processed. Kanban scan in each of the WIP/ FG inventory in and out also increase the accuracy of kanban data for better data analysis, adaptable to changing demand, and robust kanban management.

The seventh identified problem is production planning is done manually, and the schedule is distributed by a paper to the production line. It takes time to synchronize between the total production mentioned in the schedule with the correct number of circulated kanban. The proposed framework has FPS database/ module roles in production planning and calculates each of the component production schedules based on BS function on daily basis. With a dynamic GUI, the production line is able to access the schedule, and waiting for the kanban to be ordered to start the production process.

5. Conclusion and Future Work

The contribution of this work is an e-Kanban framework system for an in-house production system that employs mixed-model production line while considering the optimal calculation of production schedule, dynamic mapping of machines and operators, and automatic kanban flow order and monitoring. In general, it also applicable to the other first/ second tier OEM companies in Indonesia with similar production line.

The inefficiencies of traditional Kanban system in Indonesia's automotive mixed-model production line has been identified. An extension of the current system to e-Kanban system is proposed to solve the problems. The proposed system is an integrated tool for simultaneously calculate scheduling of the customer orders, and maintain the right number of kanbans circulation in the production line in response to the customer pulling kanban while considering the scheduling constraint. It is a combination of paper-based kanban and software-based kanban system. Paper-based kanban handles the movement of man and material in the production line. While software-based kanban system handles kanban lot-sizing, production instruction schedule, and integration with the subjected company ERP system. The proposed system is best suited for production planning and control of the manufacturing system with the batch production process of high product and volume variety, and short production time. To sum up the results, it is considered that the designed framework is suitable for countering the traditional Kanban system problems in the subjected company.

Directions for future work include the implementation of the e-Kanban system application to the production line of the subjected company. Effectiveness evaluation of the system and the development of effective charts/ graphs for data analysis will be focused; furthermore, an optimization technique for the machine and manpower efficiency will be developed.

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